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INTRODUCTION.

Wood-preservation is the treatment of wood with a strong antiseptic which, when forced into the cells by one of the many processes now used, increases the life of the wood. It is an industry which is comparatively new in the United States, but one which has grown very rapidly in the last few decades until at the present time it is a factor which is making itself felt all over the country.

Though wood is perhaps the most widely used material, it has at its best a very short life when exposed to the weather or placed in contact with the soil. No material will last forever; even steel and stone will corrode and crumble with time. But the life of wood in its natural state is not nearly as long as that of other structural materials, and while this fact did not appear to be very important fifty years ago when wood was extremely cheap and when there was apparently an unlimited supply of it, it is now a matter of vital interest. Since wood is especially adapted for certain uses and since there are no perfect substitutes for it, the problem of prolonging its life is one of great importance.

The preservation of wood does more however than merely to extend the life of timbers in common use, it also widens the field of usable woods. Inferior wood that was formerly considered valueless, will after treatment have as long as or longer life than the best of wood untreated. Several striking examples of this fact are the substitution of gum and beech

cross-ties for white oak and that of loblolly pine poles for cedar. Even though the cost of treating increases the initial cost greatly, the treated tie is found to be the more economical.

Due to the fact that the dead oil of coal tar is the only known material that effectually prevents the ravages of marine worms and prevents decay, it is therefore the best preservative and the one most widely used. As the writer's personal experience was gained at a large plant of "The Kettle River Company" located at Madison, Illinois, where he inspected both cross-ties and paving blocks treated with creosote, the creosote treatment will be discussed mainly in this paper but not however to the total exclusion of others. From time to time, the relative merits of treatments will be dealt with to show why the dead oil process is the most practical. While treated wood is used for all purposes such as bridge timbers, piles, posts, shingles, cross-ties, fence posts, and dimension timbers, references and conclusions will be made of cross-ties more particularly. This is because more extensive experiments on treated ties have been carried on than on any of the other uses and records of such tests are obtainable, and because more wood is used for cross-ties than for any of the other purposes.

WHY PRESERVING OF WOOD IS NECESSARY.

In keeping with the other resources of our country, United States was originally blessed with forests wonderful both in magnitude and quality. Until recently, the general opinion was that no matter how extravagantly wood might be used there would always be a superabundance of it; but the tremendous rate at which some of our forests have been cut down has brought the country to a sudden realization that some radical reform must be instituted at once.

The following table shows very clearly the comparison of the original forest area and stand to that of the present.

Estimate of the area and stand of the original and present forests of the United States.

Region.	Original forest.		Present forest.			
	Area.	Stand.	Area.	Stand.	Per Cent of original area.	Per Cent of original stand.
	Million acres.	Billion feet.	Million acres.	Billion feet.	Per cent.	Per cent.
Northern.....	150	1,000	90	300	60	30
Southern.....	220	1,000	150	500	68	50
Central......	280	1,400	130	300	46	21
Rocky Mountain.	110	400	100	300	91	75
Pacific......	90	1,400	80	1,100	89	79
Total....	850	5,200	550	2,500	65	48

As the table shows, the forests are divided into five regions. The Northern region includes New England, New York, Pennsylvania, Michigan, Wisconsin, and Minnesota. This forest in

which the cone bearing trees predominate and which is the home of the white pine has been depleted to a shameful extent. The Southern type extends south from New Jersey and runs west through the gulf states to Texas. This, also is a coniferous forest in which yellow pines prevailed. The Central region stretches between the Northern and Southern, from the Eastern Mountains to the Western plains. This region in which all types of hardwood predominated has been exhausted to a greater extent than any of the others. The Rocky Mountain forest as its name indicates is typical of the Rocky Mountain region, and extends from Canada to Mexico, the trees being entirely coniferous. The Pacific type of forest prevails west of the Rockies all along the coast. This timber is exclusively a cone bearing forest and the Douglas fir and the redwood are found in great abundance.

From these various forests are taken annually includint the waste in logging and in manufacture 23 billion cubic feet of wood. The following list shows the amounts of wood used for different purposes:*

Purpose		
Firewood..................	100,000,000	cords.
Lumber.....................	40,000,000,000	feet, B. M.
Posts, poles, and fence rails	1,000,000,000	
Headings..................	133,000,000	sets.
Barrel hoops...............	500,000,000	
Native pulp wood..........	3,000,000	cords.
Round mine timbers.........	165,000,000	cubic feet.
Wood for distillation......	1,250,000	cords.
Hewn ties..................	118,000,000	

*From the National Conservation Commission's Report made to President Roosevelt in January, 1909.

Until a comparatively recent time railroads were usually able to secure an ample supply of ties from lands adjoining their right of way, but the great demand for ties has made this impossible now and in forests where the tie was once the major product, it is now a minor one. In 1907 there were about 154 million ties (410 million cubic feet) purchased and over ninety per cent of these were used by steam railroads; eighty per cent were hewed ties, forty-three per cent were oak, and over twenty per cent were pine and the rest were mainly cedar, chestnut, red fir, and cypress.

It can readily be seen from the above statistics why our hardwood and pine forests have been so greatly depleted. When it is known that there is used from our forests each year, not counting the loss by fire, three and one-half times their yearly growth, or that there is used forty cubic feet per acre to each twelve grown, it can be understood why a radical movement is necessary. The fact that the United States uses two hundred and sixty feet per capita to thirty-seven used by Germany and twenty-five used by France shows that this tremendous extravagance of wood is wholly unnecessary.

MEANS OF SUPPLYING THE DEMAND.

The problem of how best to supply the increasing demand for wood is intricate and one that can only be solved by careful consideration. A few fundamental principles that must be complied with in order to deal intelligently with this problem are: first, the preservation and conservation of the forests; second, the practice of economy in the use of wood; and third, the antiseptic treatment of timber.

By preservation and conservation of the forests is meant protection against fire, a wise and intelligent cutting down of trees, and aiding the young growth. All this is included in the phrase "practice of forestry". Since 1870, no less than 50 million acres of forests have been burned over annually destroying a yearly average of fifty lives and of 50 million dollars' worth of timber. The only way of combating forest fires is to prevent them, and this can only be done by the work of trained forest rangers. Trees that are to be felled should be selected with great care and then should be trimmed more economically as one-fourth of the standing timber is lost in present methods of logging. Young growth should be protected and, moreover, trees should be set out and replace those cut down. Forestry, which is the art of conservation of forests, will have to be practiced more widely than at present, as it is now only applied to 70 per cent of the forests publicly owned and to less than one per cent of those privately

owned, or to only 18 per cent of the total area of the timber.

The practice of economy and the complete utilization of the wood after it is brought from the forests is another way of supplying this great demand. The loss in the mill alone is from one-third to two-thirds of the timber sawed. The substitution, whenever possible, of other materials for wood such as brick, stone, concrete, slate, tile, steel, and so forth is a condition that will be absolutely necessary in the near future.

However, wood will always be required for certain cases for which it is peculiarly adapted and the only possibility of meeting the demand, then, is to increase its life as much as possible. The simplest way of doing this is by seasoning, or reducing the moisture content of the wood. Since this is not permanent, the wood always reabsorbing moisture when exposed to dampness, an artificial method is employed. This method is a preserving treatment, using wood antiseptics, whereby the life of the timber is increased two or three fold.

The necessity for more land for farming purposes may reduce our total forest area by 100 million acres, but it is possible to produce on 450 million acres enough wood for a population much greater than that of this country at present. It will, however, be necessary to bring the land to its highest producing capacity and to utilize the product completely and economically. To reach this equilibrium between the production and the consumption, it will require the combined efforts of the individual forest owners, of the states, and of the National Government.

CAUSES OF WOOD DESTRUCTION.

Wood is destroyed in two distinct ways, each being very important. It may be destroyed either by natural agents such as by the low forms of plant life and by marine borers, or it may be destroyed by mechanical agents.

There are two forms of rot, the wet and the dry. Wet rot is not an inorganic process like the rusting of iron but is due to the action of low forms of plant life called bacteria and fungi. Bacteria is, of the two, the lower form of life, often consisting of but a single cell. The cells are usually colorless and multiply by the division of the parent cell. Fungi are more complicated than bacteria, frequently growing together in compact masses of tissue. Familiar examples of these forms are toadstools and "punks" which grow on the trunks of trees. Spores, very primitive substitutes for seed and so fine that they can be seen only by the microscope, are produced in great numbers by these fruiting bodies and are carried throughout the forests by the winds. They find lodgings in the dead part of a tree and in cut timber, and if the conditions be favorable, namely that there be plenty of moisture, heat and air, the spores will derive life from the woody tissues of the trees and multiply very rapidly. These are the real agents of wet decay but if any one of the above requirements, especially moisture, be lacking, the spores can not develop. The cuts on pages 9-12 show very well how the fungi attack

Untreated Loblolly Pine Ties, Showing Timber-destroying Fungus (Lenzites Sepiaria) Growing on the Ends.

Untreated Tamarack Tie Badly Decayed, Showing Fruiting Bodies of Timber-destroying Fungus.

Untreated Hemlock Ties with a Timber-destroying
Fungus Growing on Them.
(Note that almost all of these ties have fungi on them.)

Untreated Longleaf Pine Ties, One of Which Shows
Timber-destroying Fungus (Lenzites Sepiaria).

Untreated Beech Ties with a Timber-destroying Fungus (Polystictus Versicolor Fr.) Growing on the Ends--an Evidence of Decay.

Untreated Red Oak Ties with a Timber-destroying Fungus Growing on Them.. One Tie is Badly Split.

Section of Shortleaf Pine, Showing How a Fungus (Trametes Pini) Entered Through an old Burn, Destroyed the Heartwood of the Interior, and Grew Out to Form a Gruiting Body or "Bracket."

Contrast between Treated and Untreated Pine Mine Props after One Year's Service in a Colliery in the Anthracite Regions of Pennsylvania.
(The third prop from the left was treated with creosote; the fourth prop, untreated, was set at the same time.)

the wood.

Dry rot, sometimes called sap rot, is the reverse of wet rot and is due to inorganic action. It is one of the most destructive diseases to which timber is subject, and is commonly attributed to a combination of the acids found in the sap with the oxygen of the air, which produces decomposition. Unseasoned timber, in damp places with partial ventilation, soon shows signs of decay; and beams and ties which are apparently sound are found to be completely rotten on the inside. The outside shell remains sound because it becomes seasoned and free from sap.

One of the great drawbacks to the use of wooden piles in sea-water is the destruction of the timber by the small toredo or marine borer . They destroy wooden piles in a very short time to such an extent that the pile has to be replaced. The cut on page 14 shows very clearly the result of the toredo action.

Cross ties are often totally destroyed by mechanical abrasion which may result from two actions of the rail, each independent of the other. These are called "rail sawing" and "rail cutting" and both have detrimental effects upon the life of the tie. Spikes and wood screws which are used to prevent the above named abrasion are also very injurious to the ties in that they split the wood and form recesses where water collects when spikes are withdrawn.

Spruce Pile Destroyed in Three Years by Marine Borers in the Harbor of Klawock, Alaska.

PLANS FOR RETARDING THE DESTRUCTION OF TIMBER.

The simplest way of prolonging the life of timber exposed to the attacks of bacteria and fungi is to reduce the moisture content. The amount of water in green timber varies nearly as its distance from the center of the tree. Sapwood which composes the outer layers of the trunk contains most of the moisture, the heartwood containing a much smaller part. The sapwood also contains large amounts of organic matter which serves as an excellent food for the wood destroying plant life. Therefore, it is this part of the tree that is most susceptible to the attacks of the fungi since the heartwood, due to its dryness, is more durable. For example, if the wood be allowed to season thoroughly before it is used, the moisture content will be reduced to about fifteen per cent and the life and strength of the wood consequently will be greatly increased.

Seasoning does not preserve the wood however for any length of time if it be exposed to damp conditions as moisture will again be absorbed, thus causing the wood to be in prime condition for growth of the fungi. A far better method for checking this growth is to poison the food supply by injecting powerful antiseptics immediately after the wood is seasoned. This is more permanent in that it not only poisons the wood but also prevents the reabsorbing of moisture to a great extent, since preservatives clog up the cells of the timber. It is a known fact that the ancients were accustomed to paint their

statues with oily and bituminous preparations to keep them from decay. Pettigrew extracted the preservative fluids from the heart of an Egyptian mummy that had resisted decay for over 3000 years, and found that decomposition immediately began.

As has been said, unless structural timbers and especially cross-ties are protected against mechanical abrasion, the preserving of the wood is of little value. Experience has shown that the present rail fastenings are fairly satisfactory when used with hardwood ties, but they are by no means adapted to those of softwood. To protect the softer woods, tie plates must be used and this is absolutely essential if the life of the tie is to be lengthened.

HISTORY AND GROWTH OF CHEMICAL PRESERVATION.

Chemical preservation of wood is of a comparatively recent origin in the United States, though it has been used for many years in Europe with great success. This has been so because of very different conditions; for years wood has been scarce and high priced there, thus Europe was forced to use heavy preservative treatments over a hundred years ago. In a paper before the "Wood Preservers' Association", Mr. Octave Chanute stated that wood preservation in United States dated back to 1876 for piles and timber and to 1885 for ties. One of the pioneer plants (now owned by the Louisville and Nashville Railroad), was built at West Pasagoula in 1876. This plant has used creosote entirely, and has continued in operation until the present. As creosote was formerly very expensive, numerous inventors proposed cheaper ways of using it, such as reducing the oil to vapor and then injecting it, thereby obtaining a greater penetration with less amount, by dipping the wood into hot coal tar, and by boiling the timber in hot creosote. These cheap methods proved to be total failures.

In 1885, the Santa Fe Railroad erected a zinc tannin plant at Las Vegas and obtained some very good results. The next year, the Union Pacific Railroad built a plant at Laramie, Wyoming, and a few years later the Rock Island erected a plant at Chicago. Since then the industry has grown very rapidly. In 1908, 23,776,060 ties were reported by steam and electric roads

as having been treated by them or purchased already treated. This was 21.1 per cent of all the ties purchased in that year. The corresponding percentages in 1907 and in 1906 were 12.9 and 11.5, respectively. Twelve large railroad companies are now running treating plants of their own, and a number of other roads either buy treated ties or have them treated at commercial plants. Altogether, there were in operation in the United States in 1908 about 70 wood preserving plants. The following map (from Forest Service Bulletin No. 78) shows the location of these plants, most of them being near forests or else on railroads that have easy access to the timber.

Map showing the location of the timber-preserving plants in the United States.

VARIOUS ANTISEPTICS USED FOR PRESERVING WOOD.

There have been many different antiseptics used in the treatment of timber, and as in every thing else, the best have survived. A few of the principal antiseptic processes now or formerly used, such as the kyanizing process, the zinc-tannin, the copper sulphate, the burnettizing, the creosoting, and the Card process, will be discussed briefly.

The kyanizing process was invented and introduced in England in 1832 by J. H. Kyan. It consists in steeping the wood in a solution of corrosive sublimate, the degree of solution usually being one pound of the salt to ninety-nine pounds of water. It was used for a number of years in both England and America and while the bichloride of mercury is undoubtedly a good antiseptic, this process has practically gone out of use. This was because of the great cost of the corrosive sublimate and of the length of time required for treating, a day usually being needed for each inch of the least thickness of the timber.

The zinc-tannin or Wellhouse process consists of treating seasoned wood with zinc chloride, glue and tannin solution, under pressure. The wood is first steamed from four to six hours with live steam at 20 to 30 pounds pressure and is then subjected to a vacuum of from 18 to 26 inches. After the sap and moisture have been withdrawn, a one and a half to three per cent solution of zinc chloride with one half of one per cent in weight of dissolved glue is introduced and held under pressure

of 100 pounds for a period of three to six hours. The retort is then freed by forcing the chloride solution back into its receptacle and the tannin is introduced. About two hours are required to force this into the wood, the process then being complete. Though this method of treating wood proved to be fairly successful, it is used very little now, the burnettizing process having replaced it.

Copper sulphate is another antiseptic that has been used in the treatment of wood. While it is a strong preservative, it was not used for a very long time, due perhaps to its great cost.

The burnettizing or commonly called zinc chloride process of preserving wood is one that is widely used in United States. It differs from the Wellhouse treatment only in the fact that it does not use either the glue or the tannin. The zinc chloride process is a very good one and is much cheaper than the others. It has the great disadvantage however, of the salt leaching out when exposed.to moisture, thus leaving the wood in its original condition. This leached out salt is also known to have interfered with electric block systems of railroads by short circuiting the connections.

The creosoting or Bethel process consists of injecting hot creosote oil into wood in quantities sufficient to preserve it. It was invented by John Bethel in 1838 but was used very little until 1885. Since then its use has become very extensive and it is now used more than any of the other processes. While it is the most expensive treatment, it is the most economical,

since it fulfils all requirements better, thereby giving the wood a longer life. The method of treating is the same as in the zinc-tannin process. Since the benefits from steaming are doubtful, this is very often omitted.

The Card process is a combination of the creosote and the zinc chloride processes. About 15 per cent of creosote is used, the remainder being a three to five per cent solution of zinc chloride. The oil which is injected last tends to prevent the salt from leaching out, thereby making a cheap but effective treatment.

PROCESSES OF TREATING.

There are a number of different processes for treating wood but only a few of them have proved to be practical. Perhaps the oldest method is the open tank process. It consists in heating seasoned timber in a hot liquid bath from one to six hours. During this treatment the air and moisture in the wood expand and a portion of them pass off. If oil is used, the volatile part can be collected over the vessel, condensed and used again. At the end of the hot bath, a quick change is made to a preservative at a lower temperature. This causes a contraction of the air and moisture remaining in the wood, thereby producing a vacuum which can be destroyed only by the entrance of the preservative. Thus atmospheric pressure accomplishes what is done by artificial pressure in most of the commercial plants. While this process works very well for light treatments and for small plants where pressure equipment is too costly, it does not replace in any way the pressure process.

The essentials of the apparatus in the pressure process are the sealed retort and the pressure pump. The retort is usually a horizontal cylinder of any length up to 175 feet with a diameter of from seven to nine feet. The cylinder must be capable of withstanding high pressure and the two doors so arranged that they can be easily closed and made air tight. After the timber is drawn in on iron trucks and the doors closed,

live steam is admitted and a pressure of from 20 to 40 pounds per square inch is maintained for several hours. (In many plants steaming is omitted because of the injury to the wood). When the steam is at last blown out of the retort, the vacuum pumps are started and as much as possible of the air and moisture is exhausted from the wood. This part of the process continues from a half an hour to two hours, an 18 to 26 inch vacuum being drawn. The preservative is then run into the cylinder at a temperature of about 150° C. and the pressure pumps operated until the desired amount of preservative is forced into the wood. This requires from one to six hours time with a pressure of from 25 to 175 pounds, depending upon the kind of wood used and the amount of preservative required. The surplus of the preservative is then forced back into the storage tanks, the wood is allowed to drip a few minutes, and finally the doors are opened and the treated timber is withdrawn. This process of treating timber is used almost universally in Europe and America.

Due to the fact that the pressure or full cell process requires a large amount of creosote when oil is used, many men have tried to obtain an equally good penetration with less oil. These are called the empty cell processes and consist in withdrawing part of the creosote with a vacuum after it has been injected into the wood cells. One of the best known of these processes is the Rüping process. It is much the same as the pressure process except that the steaming and the drawing of the vacuum are omitted. The wood is first subjected to an air pressure of about 75 pounds until the interior spaces of the

wood are filled. Then oil is admitted at a somewhat stronger pressure--probably 80 to 85 pounds--and after the timber is all covered, the pressure is increased to about 225 pounds. This forces the oil to penetrate into the interior of the wood. Finally, the valves are opened, the oil is run back to the storage tanks and the compressed air in the wood cells assisted by the vacuum pumps force out a large amount of the preservative. Thus a good penetration is obtained with a small amount of oil.

Another well known empty cell process is the one invented by Mr. C. B. Lowry. The Lowry process is very similar to the Rüping, except that no compressed air is used. The oil under pressure is applied immediately after the doors are closed. This compresses the air in the wood so that when the pressure is released, a large part of the oil is forced out by the air, which is also assisted by the vacuum pumps.

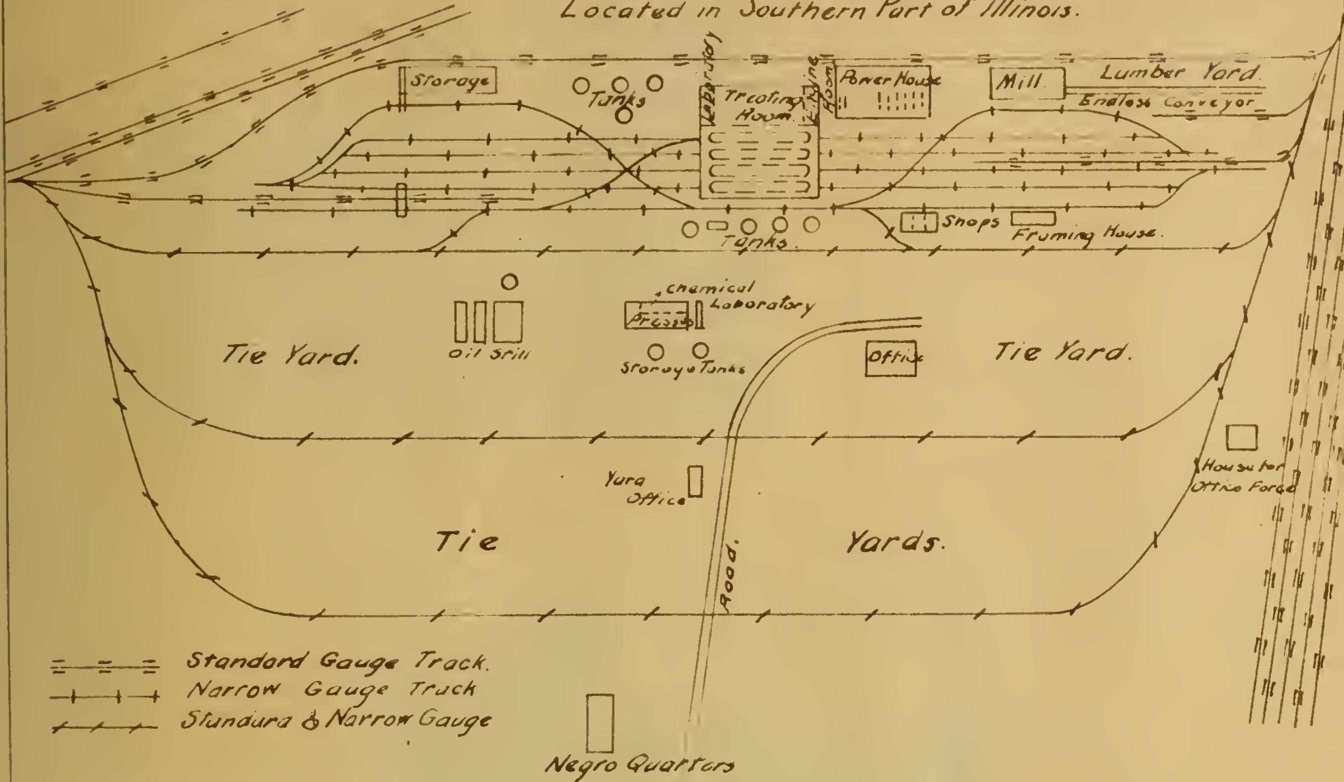
GENERAL PLAN OF A WOOD PRESERVING PLANT USING PRESSURE PROCESS.

The plate on page 26 shows the plan in rough of a large wood preserving plant located in the southern part of Illinois. It is a well equipped plant; is exceptionally convenient to numerous railroads, and has a capacity of about 15,000 cross-ties per day. The tie-yards are large enough to season about two million ties. The plant can treat paving blocks, piling, bridge timbers, cross arms, pins, and ties with creosote, zinc chloride, or a combination of the two. However, the creosote treatment is used mainly. The first two cuts on page 27 show the cylinder room and storage tanks of this plant; the third cut shows a small oil-still used for refining crude oil. Most of the creosote used there, however, is purchased in a refined state.

Cuts one and two on page 28 show similar though smaller plants. Cuts three and four on the same page show the retorts or cylinders commonly used in the pressure process. The method of fastening the heavy doors, making them air tight, can readily be seen. Cut three is a portable plant that railroads often use, moving it from one place to another according to their needs.

General Plan Of A Wood Preserving Plant.

Located in Southern Part of Illinois.



Cylinders And Pump Connections Of Above Plant.

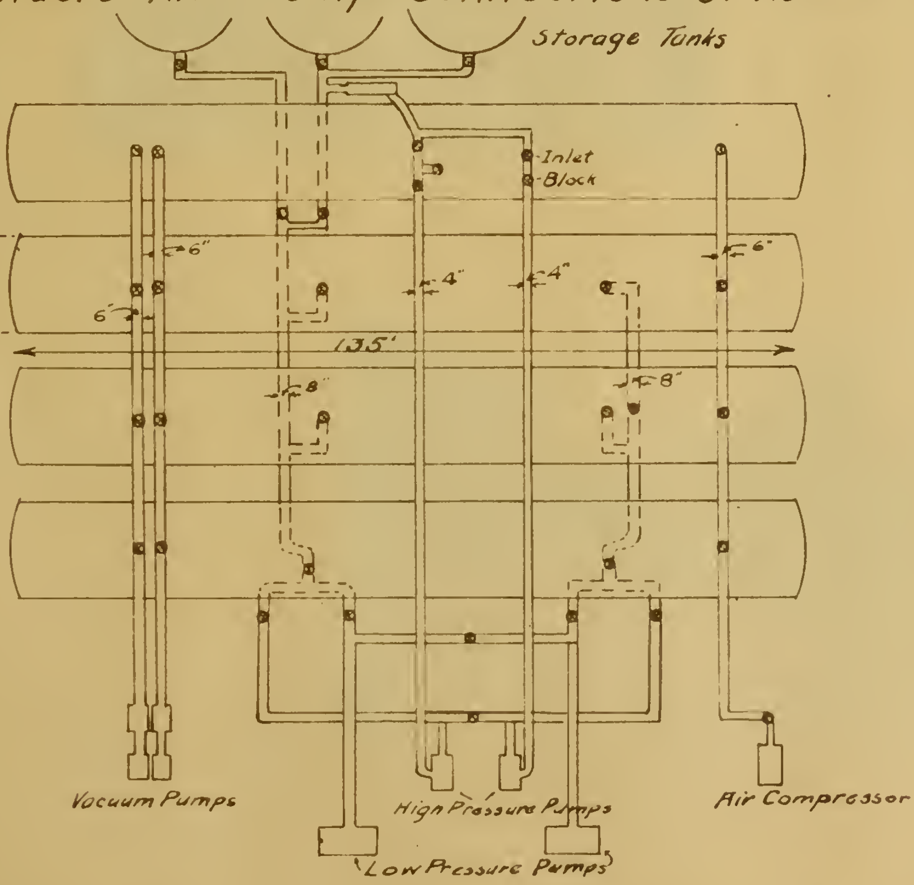


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1.

Timber-Preserving Plant of the Pennsylvania Railway Co. at Mt. Union, Pa.

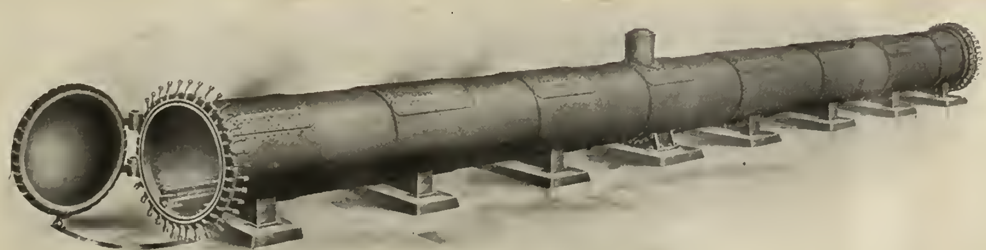
Fig. 2.

Timber-Preserving Plant of the Eppinger & Russell Co. at Jacksonville, Fla.

Fig. 3.

Union Pacific Railroad

Fig. 4.



SEASONING.

Seasoning is the more or less rapid evaporation of water from the wood. As seasoning progresses the strength increases, so that by simply drying a piece of green wood, it is possible to multiply its strength from two to four times. Stiffness is similarly increased by drying, though less markedly. Investigations by the Forest Service have determined that seasoned timber not only has a longer life than green wood when in contact with the soil, but also that it is more receptive of preserving solutions.

Moisture exists in green wood in two conditions, that which is in the substance of the cells and that which fills the pores or the lumina of the cells, similar to honey in a comb. The latter, which is called "free" water has no direct influence upon the strength. The cell walls will under certain conditions become saturated with water and will absorb no more though the wood may absorb free water. The point at which the cells reach maximum absorption is about 30 per cent moisture based on the dry weight of the wood and is known as the fiber saturation point. After this point is reached added moisture does not lessen the strength of the wood nor does the wood swell any more. Starting with the absolutely dry conditions, it can be seen from the diagram on page 30 that with increase of moisture the strength falls off very rapidly at first, then more slowly until the fiber

saturation point is reached where it abruptly ceases to decrease, so that the diagram for the moisture per cents becames a horizontal line. The moisture in green wood when air seasoned in this climate dries to from 8 to 16 per cent of the dry weight of the wood according to the humidity of the air. When this equilibrium point is reached, the wood is considered to be dry.

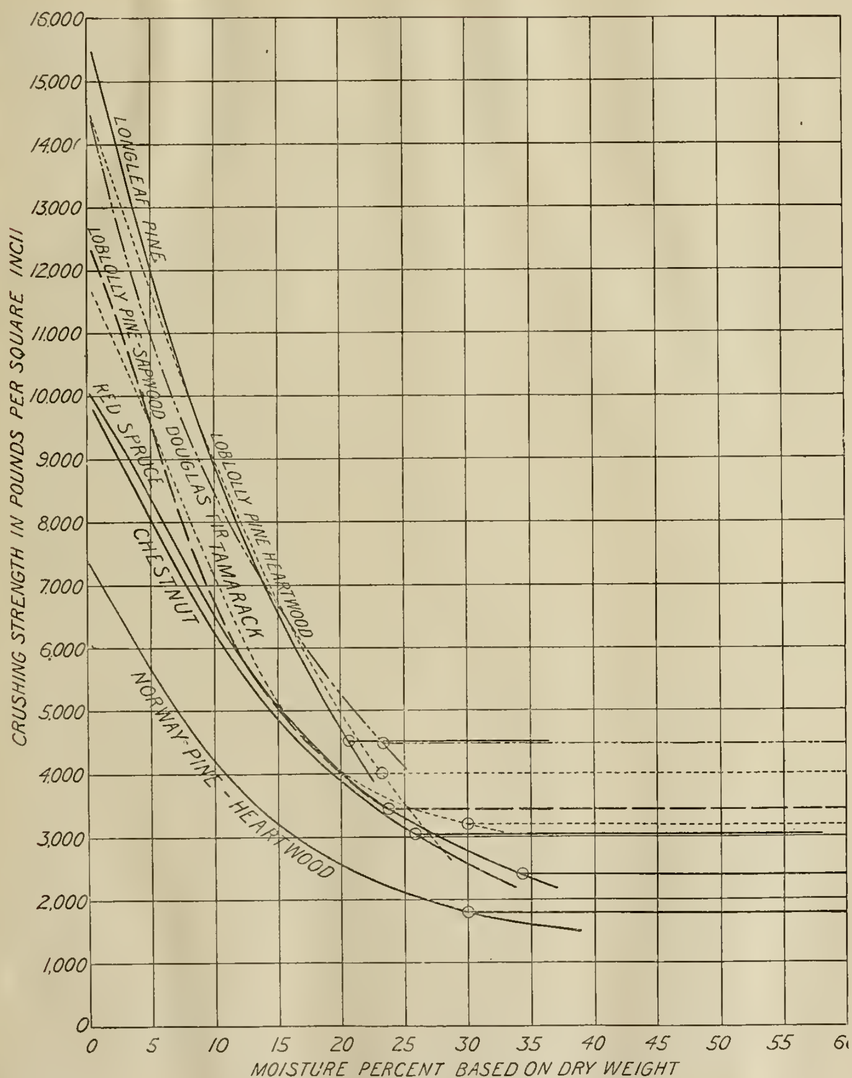


FIG. 1.—Relation between the crushing strength in compression parallel to grain, and the moisture content for several woods.

Since the season of cutting timber makes a great difference in the length of time in which it takes the wood to dry, in the manner in which it dries, and its receptive powers for absorbing preservatives, particular care should be taken to see that the wood is cut at the right time. The best time for cutting timber is from November to April, inclusive, as the sap is down then and as the wood dries out with less checking. There are two distinct forms of checks that occur in wood, the radial and the honeycomb. The two forms may be seen in the following cut, the radial being the most destructive, often making the wood unfit for use.

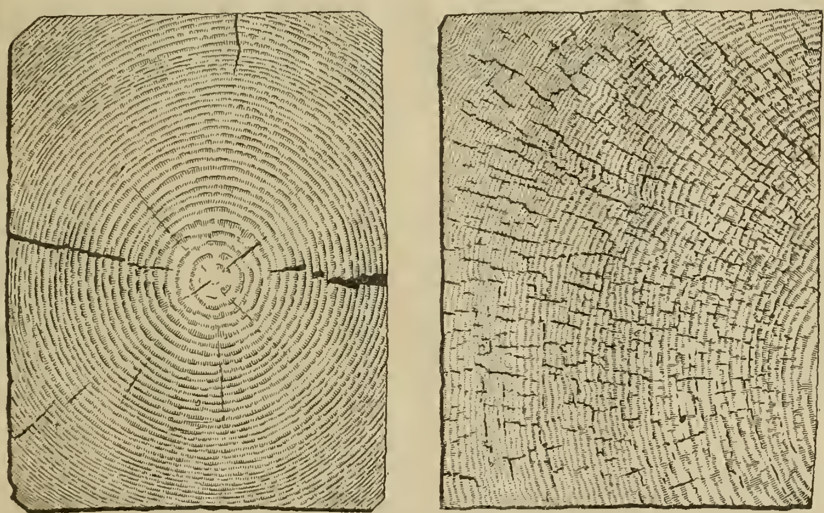


FIG. 1.—Radial and honeycomb checks.

Honeycomb checks occur on wood which seasons slowly during the first few months, while radial checks occur on timber which seasons rapidly during the first few months, that is, timbers which are cut during the period from June to September. For this reason, wood should not be allowed to be cut during this

period. In fairly dry climates, timber should be seasoned at least three to four months before it is treated with creosote oil. This will be sufficient time if the wood is peeled and piled in isolated groups so that the air can get at each piece. For most species of wood, it is very advantageous to peel all ties as soon as they are cut, since this allows them to dry more unifromly and quickly.

PROPER GROUPING OF TIMBER FOR TREATMENT.

Since no two species of wood have the same rate or degree of absorption of preservatives, it is very important that similar woods be treated together. If this is not done, one cross-tie may have a very much greater penetration and absorption than another tie in the same cylinder charge. For instance, if pine and oak were treated together, the pine would easily absorb twice as much creosote as the oak. Because uniformity of treatment is absolutely essential if wood preservation is to be practical, it is very necessary that timber be treated according to its absorption abilities. It is best of course to treat wood of the same species together, but since this is not always practical, a grouping of timber has to be decided upon. Perhaps the best grouping known is the one worked out by the Chicago, Burlington and Quincy Railroad Plant at Galesburg, Illinois, where they drew their conclusions from experiments upon about 20,000 ties. This plant subdivided wood into three classes according to its power of absorption; class A, absorbing less than 22 per cent in volume; class B, absorbing between 23 and 30 per cent; and class C, absorbing more than 30 per cent. The table on the following page shows this classification.

Not only should timber be grouped according to its absorption powers, but also according to whether it is sap wood

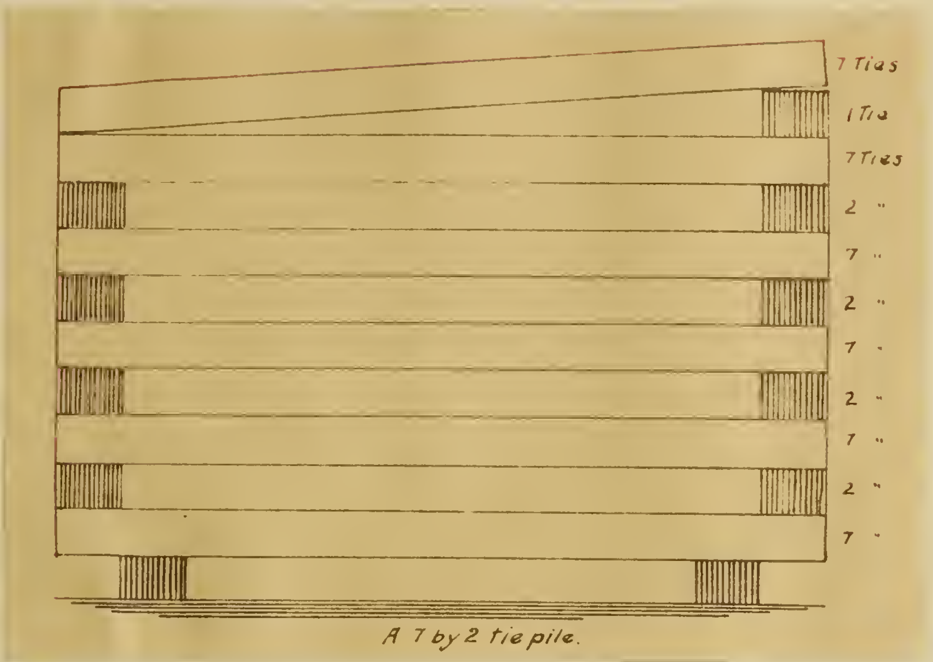
CLASSIFICATION OF TIE TIMBER.

C., B. & Q. Timber Preserving Plant, Galesburg, Ill.

KIND OF WOOD	No. of Ties Used in Test	Absorption in volume Per Cent.	No. of Months Seasoned in Yard
CLASS "A"			
Oak, Red.........	3112	20.9	6 to 15
Oak, Pin.........	671	19.5	10
Oak, White.......	731	14.2	7
Hickory..........	414	18.8	2 to 8
Beech............	2481	21.8	15
Hemlock..........	1364	20.7	8 to 15
Tamarack.........	2329	17.1	6 to 8
CLASS "B"			
Sweet Gum........	928	23.0	5 to 9
Chestnut.........	345	22.6	12
Hard Maple.......	691	28.3	15
Ash..............	318	23.0	2 to 6
Sycamore.........	364	26.6	7
Poplar...........	1348	26.8	7 to 9
CLASS "C"			
Shortleaf Pine...	2192	36.9	5 to 9
Soft Maple.......	599	33.1	6
Tupelo Gum.......	790	30.7	8
White Elm........	872	36.6	7 to 15
Red Elm..........	626	34.9	6 to 9
Cypress, White...	662	35.4	7 to 8
Red Birch........	775	33.0	6 to 9
Cottonwood.......	621	39.2	4 to 7

or heartwood, whether it has been seasoned to a dry condition or not, and according to its size. The reasons for this are apparent, as the amount of oil absorbed depends upon these variables. A standard classification of sizes is to put everything three inches and under in one class; four to six inch material in another; eight to ten inches together, and everything above ten inches in another class.

As it is important that wood be treated according to species, the question arises, where is the better place to sort the timber, at the place of shipment or at the preserving plant. It is generally conceded that it is more practical and economical to have the separating done at the former place and shipped this way to the plant. This saves the attempt at sorting the wood in a crowded storage yard as it is taken from the cars. Where the cross-ties are already separated, they can be carried directly out of the freight car and piled in the yard. It is essential for thorough seasoning that the ties be piled so that air can reach all sides. A number of different methods of doing this have been used, but a "seven by two" pile as shown in the cut on page 36 has probably proven to give the most satisfaction. Such a pile can be made as high or higher than the freight cars to good advantage. When piled in this way and allowing plenty of space between piles, required storage space is sometimes figured by allowing a tie to each square foot of area.



The best form of pile for seasoning ties quickly and uniformly.

STEAMING.

The first step in the pressure treatment of wood after it is seasoned is steaming. The wood, placed upon trucks or car buggies is run into the retort, the doors are closed and live steam is admitted, preferably at the ends. A blow-off at the top is kept open until all the air has escaped. The steam pressure and the length of time that it is held varies with different operators from 20 to 40 pounds pressure and a length of time of from one to ten hours. Twenty pounds pressure held for two hours is quite commonly used.

Though wood has been steamed in the pressure process for many years, the value of this part of the treatment is doubtful, so that it has been dispensed with fully in many plants and partly in others. Especially is this so west of the Appalachian mountains. Steam is supposed to open the pores of the timber and loosen and expel the natural saps, but while it may do this, it is claimed by many authorities that its real value is in its ability to warm the wood and this only to moderate temperatures. One of the great disadvantages of steaming is that it weakens the strength of the wood, this being due to the excessive temperature conditions. This diminution of the strength of wood depends largely upon the species of wood, the degree of seasoning, and upon the character of growth in the different parts of the tie. Since the weakening is due to heat,

any cause which protects the wood from the heat will tend to diminish the resulting loss. Thus green ties will suffer less from the action and the duration of a given pressure than well-seasoned wood. Hard summerwood suffers less than springwood, and heartwood less than sapwood. The effect of high temperatures upon wood is to produce a visible discoloration and this scorching is very frequently found in wood that has been steamed. Some discs taken from the cross-section of loblolly ties about one inch from the surface were discolored at 40 pounds pressure and suffered more seriously as the pressure increased. Sixty-four per cent of the discs were scorched badly at 50 pounds pressure and 94 per cent at 100 pounds. Thirty-eight per cent of the discs showed discoloration from five hours of 20 pounds steam pressure. This pressure corresponds to about 260° F., though the temperature inside of the tie would not be over 210° F.

Some experiments made upon loblolly pine ties at St. Louis by Mr. W. K. Hatt showed that steaming four hours at 20 pounds pressure reduced the strength of the ties fully 15 per cent, and that the loss increased directly with the pressure and its duration, the loss ranging from 40 to 60 per cent after steaming at 100 pounds for four hours and exceeding 30 per cent after steaming at 20 pounds for twenty hours. Even the effect of live steam at so-called "safe" temperatures is injurious to the wood. It is safe to say that during steaming the amount of moisture in an air-dry timber is increased, with a consequent decrease in strength, and that the succeeding vacuum fails to remove all of the added moisture before the introduction of the

preservative. In a railroad test track laid in Texas, a great many treated ties had to be removed shortly after laying, due to brittleness and weakness. These defects were caused by steaming and high temperatures.

Due to the above facts that steaming is unnecessary and injurious, and to the fact that it is very expensive and therefore greatly increases the cost of preservative treatment, many treating plants have dispensed with it. Mr. Octave Chanute stated before the Wood Preservers' Association that in treating seasoned wood, or wood in any condition that is to be treated with creosote, the steaming process should be omitted. Many other leading treating engineers also emphasize this. When green wood is to be treated with zinc chloride, it may be permissable to use steam, as the heated air then acts as a motive power to clear out sap cells, but in general it would be better if steaming was omitted. In tests made by Mr. Hatt at La Fayette, Indiana, on some loblolly pine ties creosoted without steaming, it was found that the precess had not weakened the wood, and that since no steam was used, a degree of seasoning resulted which had the effect of making the wood stronger.

PRODUCING THE VACUUM.

If wood has been steamed, it will be necessary to withdraw all vapors and condensations of the steam and volatilized saps from the retort before the oil can be admitted. This is done by the use of one or more vacuum pumps. If the wood has not been steamed, a vacuum always aids the subsequent treatment by withdrawing more or less matter from the wood cells and passages, thereby leaving the timber in a more receptive condition. However, if the wood has been seasoned properly, there will be very little moisture or sap freed by the vacuum. If steaming is omitted and the drawing of the vacuum is the first step in the pressure process, this assists greatly in closing the retort doors air tight as it is no simple matter to do this without the aid of the vacuum. With a vacuum in the cylinder, thereby procuding an air pressure of 10 to 14 pounds per square inch on the doors, it is fairly easy for the men to tighten the bolts so that the retort is air tight. The height of the vacuum and the length of time that it is held varies, as do other parts of the treatment, with the management of the plant. It is customary in most places to draw a vacuum of from 30 minutes to two hours, it varying according to the condition of the wood and the amount of preservative that is to be injected. Then, without decreasing the vacuum, the creosote previously heated in the storage tanks by steam coils to about

120° F., is admitted. This is done by opening the valve under the retort leading to the creosote reservoir, when the fluid rises through the action of atmospheric pressure so as to fill the retort partially, the remainder of the filling and the application of pressure being effected by means of pressure pumps. As soon as the oil is ready for these, the vacuum pumps are stopped.

APPLICATION OF PRESSURE.

When the creosote has been admitted to the retort, the oil is then ready for the pressure pumps. During this part of the treatment, the temperature in the cylinder is held at about 150° to 175° Centigrade, as the higher the temperature, the more fluid is the oil. High fluidity is valuable as the creosote is more easily injected, thereby requiring a lower pressure. The required pressure also varies with the amount of oil and penetration desired, with the specific gravity of the oil, and with the kind of timber to be treated.

The amount of creosote to be injected depends upon the intended use of the wood. Experience has established the fact that wood for marine work exposed to the action of toredos requires a heavy treatment of 20 or 22 pounds per cubic foot. On inland work, for round and sheet piling, a 15 pound treatment is advisable, and for telegraph and telephone poles, twelve pounds per cubic foot is necessary. Wood paving blocks require a 16 to 20 pound treatment and cross-ties ten pounds per cubic foot unless tie plates are used, when it is advisable to use a larger amount.

The specific gravity of the oil usually ranges from 1.05 to 1.12, the lighter being the easier to inject.

The kind of wood and its condition with respect to seasoning makes the greatest difference in the required pressure on the oil and length of time which is necessary for proper in-

jection. A soft wood, well seasoned can often be treated with as low a pressure as 25 pounds per square inch in 15 minutes. In such a case as this, air pressure instead of oil pressure is often applied. When refractory woods such as oak poorly seasoned are treated, an oil pressure as high as 175 pounds may be required and may have to be held for six hours or more to procure the desired absorption and penetration. A slow treatment usually gives a better penetration in the wood than a fast one. There is no fixed rule to determine how long the pressure must be applied or what pressure to use. The treating engineer can determine this only by watching the gauges for each charge and from these, calculate the amount of oil absorbed per cubic foot or per tie.

The amount of wood in cubic feet that is run into the cylinder is first computed*, or if the wood is cross-ties, the number is counted. From this the amount of oil to be injected is figured. The storage tank gauge is read before the oil is admitted and then after the cylinder is full, also the corresponding tank temperature is always taken. From this volume-reading is subtracted the amount that the wood is to absorb, allowance being made for initial absorption. This is the low point for the gauge and pressure is put on until the oil in the tank reaches it. The oil is then ready to be forced back from the retort and this is commonly done with air pressure. The gauge is again read and the difference between this reading and the first one gives the amount of oil injected. As the

*The first table on the following page will be found of service in figuring the cubical contents of piling.

CUBICAL CONTENTS OF PILING.

Large Diam.	SMALL DIAMETERS.														Large Diam.
	6'	6½"	7"	7½"	8"	8½"	9"	9½"	10"	10½"	11"	11½"	12"	12½"	13"	
8"	.2691	.2877	.3072	.3277	......	......	......	......	......	......	......	......	......	......	......	8"
8½"	.2895	.3086	.3286	.3495	.3713	......	......	......	......	......	......	......	......	......	......	8½"
9"	.3109	.3304	.3509	.3722	.3945	.4177	......	......	......	......	......	......	......	......	......	9"
9½"	.3332	.3532	.3740	.3958	.4185	.4422	.4668	......	......	......	......	......	......	......	......	9½"
10"	.3563	.3768	.3982	.4204	.4436	.4676	.4927	.5186	......	......	......	......	......	......	......	10"
10½"	.3804	.4013	.4232	.4459	.4695	.4940	.5195	.5459	.5731	......	......	......	......	......	......	10½"
11"	.4054	.4268	.4491	.4722	.4963	.5213	.5472	.5740	.6017	.6304	......	......	......	......	......	11"
11½"	.4313	.4531	.4759	.4995	.5241	.5495	.5759	.6032	.6313	.6604	.6904	......	......	......	......	11½"
12"	.4583	.4804	.5036	.5277	.5527	.5786	.6054	.6331	.6617	.6913	.7217	.7531	......	......	......	12"
12½"	.4858	.5086	.5322	.5568	.5822	.6086	.6359	.6640	.6931	.7231	.7540	.7858	.8186	......	......	12½"
13"	.5145	.5376	.5618	.5868	.6127	.6395	.6672	.6959	.7254	.7558	.7872	.8194	.8526	.8867	......	13"
13½"	.5440	.5676	.5922	.6177	.6440	.6713	.6995	.7286	.7586	.7895	.8113	.8540	.8876	.9222	.9577	13½"
14"	.5745	.5985	.6236	.6495	.6763	.7040	.7327	.7622	.7927	.8240	.8563	.8894	.9235	.9585	.9945	14"
14½"	.6058	.6304	.6559	.6822	.7095	.7377	.7668	.7968	.8281	.8595	.8922	.9258	.9604	.9958	1.0322	14½"
15"	.6381	.6631	.6890	.7158	.7436	.7722	.8017	.8322	.8636	.8959	.9290	.9631	.9981	1.0340	1.0708	15"
15½"	.6713	.6967	.7231	.7504	.7786	.8077	.8377	.8686	.9004	.9331	.9667	1.0013	1.0367	1.0730	1.1103	15½"
16"	.7054	.7313	.7581	.7858	.8145	.8440	.8745	.9058	.9381	.9712	1.0053	1.0403	1.0762	1.1131	1.1508	16"
16½"	.7404	.7667	.7940	.8222	.8513	.8813	.9122	.9440	.9767	1.0103	1.0449	1.0804	1.1167	1.1540	1.1921	16½"
17"	.7763	.8031	.8308	.8595	.8890	.9195	.9508	.9831	1.0163	1.0503	1.0853	1.1212	1.1581	1.1958	1.2344	17"
17½"	.8131	.8404	.8685	.8977	.9276	.9585	.9903	1.0231	1.0567	1.0912	1.1268	1.1631	1.2003	1.2385	1.2776	17½"
18"	.8508	.8785	.9072	.9367	.9672	.9985	1.0308	1.0640	1.0980	1.1331	1.1690	1.2058	1.2435	1.2822	1.3217	18"
18½"	.8894	.9176	.9467	.9767	1.0076	1.0394	1.0722	1.1058	1.1403	1.1758	1.2122	1.2494	1.2876	1.3267	1.3667	18½"
19"	.9290	.9577	.9872	1.0176	1.0490	1.0813	1.1145	1.1485	1.1836	1.2194	1.2562	1.2940	1.3326	1.3721	1.4126	19"
19½"	.9695	.9986	1.0286	1.0594	1.0913	1.1240	1.1576	1.1922	1.2276	1.2640	1.3013	1.3394	1.3785	1.4185	1.4594	19½"
20"	1.0108	1.0404	1.0708	1.1022	1.1344	1.1676	1.2017	1.2367	1.2727	1.3094	1.3471	1.3858	1.4253	1.4658	1.5071	20"

Explanation.—Multiply the tabular number corresponding to the large and small diameter of each pile, by its length in feet.

To find the diameter of end of pile, take the mean of the longest diameter and one at right angles thereto, in each case working to the nearest half inch.

(Table furnished by Mr. E. O. Faulkner, Manager Tie and Timber Department, A., T. & S. F. Ry. Co.)

temperature of the oil makes a great difference in its volume, it is customary to refer all computations to the volumes at 100° Centigrade of Fahrenheit according to which system is used. The The tables on this and the following page give constants to be used in these calculations.

FACTORS TO BE USED FOR DETERMINING THE VOLUME OF CREOSOTE OIL AT 100 DEGREES C., WHEN THE OIL IS AT TEMPERATURES RANGING BETWEEN 105° C. AND 210° C.

Temp. Cent.	Factor	Temp. Cent.	Factor	Temp. Cent.	Factor	Temp. Cent.	Factor
105	1.0020	135	1.0162	165	1.0298	195	1.0438
110	1.0040	140	1.0183	170	1.0319	200	1.0460
115	1.0070	145	1.0204	175	1.0341	205	1.0493
120	1.0091	150	1.0225	180	1.0373	210	1.0515
125	1.0111	155	1.0246	185	1.0391		
130	1.0131	160	1.0278	190	1.0417		

Explanation--Similar to that accompanying following table.

FACTORS TO BE USED FOR DETERMINING THE VOLUME OF CREOSOTE OIL AT 100 DEGREES F., WHEN THE OIL IS AT TEMPERATURES RANGING BETWEEN 60 AND 225 DEGREES F.

Temp. Fahr.	Factor.	Temp. Fahr.	Factor.	Temp. Fahr.	Factor	Temp. Fahr.	Factor.
60	0.9822	102	1.0009	144	1.0196	186	1.0382
1	0.9827	3	1.0013	5	1.0200	7	1.0387
2	0.9831	4	1.0018	6	1.0204	8	1.0391
3	0.9836	5	1.0022	7	1.0209	9	1.0396
4	0.9840	6	1.0027	8	1.0213	190	1.0400
5	0.9845	7	1.0031	9	1.0218	1	1.0404
6	0.9849	8	1.0036	150	1.0222	2	1.0409
7	0.9853	9	1.0040	1	1.0227	3	1.0413
8	0.9858	110	1.0045	2	1.0231	4	1.0418
9	0.9862	1	1.0049	3	1.0236	5	1.0422
70	0.9867	2	1.0053	4	1.0240	6	1.0427
1	0.9871	3	1.0058	5	1.0245	7	1.0431
2	0.9876	4	1.0062	6	1.0249	8	1.0436
3	0.9880	5	1.0067	7	1.0253	9	1.0440
4	0.9885	6	1.0071	8	1.0258	200	1.0445
5	0.9889	7	1.0076	9	1.0262	1	1.0449
6	0.9894	8	1.0080	160	1.0267	2	1.0453
7	0.9898	9	1.0085	1	1.0271	3	1.0458
8	0.9902	120	1.0089	2	1.0276	4	1.0462
9	0.9907	1	1.0094	3	1.0280	5	1.0467
80	0.9911	2	1.0098	4	1.0285	6	1.0471
1	0.9916	3	1.0102	5	1.0289	7	1.0476
2	0.9920	4	1.0107	6	1.0294	8	1.0480
3	0.9925	5	1.0111	7	1.0298	9	1.0485
4	0.9929	6	1.0116	8	1.0302	210	1.0489
5	0.9934	7	1.0120	9	1.0307	1	1.0494
6	0.9938	8	1.0125	170	1.0311	2	1.0498
7	0.9943	9	1.0129	1	1.0316	3	1.0502
8	0.9947	130	1.0134	2	1.0320	4	1.0507
9	0.9951	1	1.0138	3	1.0325	5	1.0511
90	0.9956	2	1.0143	4	1.0329	6	1.0516
1	0.9960	3	1.0147	5	1.0334	7	1.0520
2	0.9965	4	1.0151	6	1.0338	8	1.0525
3	0.9969	5	1.0156	7	1.0343	9	1.0529
4	0.9974	6	1.0160	8	1.0347	220	1.0533
5	0.9978	7	1.0165	9	1.0351	1	1.0538
6	0.9983	8	1.0169	180	1.0355	2	1.0542
7	0.9987	9	1.0174	1	1.0360	3	1.0547
8	0.9992	140	1.0178	2	1.0365	4	1.0551
9	0.9996	1	1.0183	3	1.0369	5	1.0556
100	1.0000	2	1.0187	4	1.0373	..6	......
1	1.0004	3	1.0192	5	1.0378	...	......

Explanation--To determine the volume at 100 degrees Fahrenheit, divide the volume at any temperature by the factor corresponding to that temperature in the above table.

Due to incorrect assumptions as to the initial absorption and to temperature variations, it is frequently found that the required amount of oil has not been injected. The valves then have to be opened again and additional oil forced in. After the final forcing back, the wood is allowed to drip a few minutes before it is withdrawn. On the next page is duplicate treating report used at the Kettle River Company of several charges of red oak and soft wood ties and of several charges of loblolly paving blocks.

Another method of determining the amount of oil absorbed by each charge is to weigh the tram load just before and just after creosoting; the difference showing the weight absorbed. This method is very little used as it requires more labor and apparatus. Each tram car has to be weighed separately and the computation made of the sap withdrawn by the vacuum.

TREATING REPORT

REPORT No. 47

THE KETTLE RIVER COMPANY

MADISON, ILL., ...191.......

Charge No.	964	1202	1275	1436	1438	1439	1440
Cylinder	3	3	4	4	3	4	4
Day in	6/30	8/6	8/16	9/10	9/10	9/10	9/10
Day out	6/30	8/6	8/16	9/10	9/10	9/10	9/10
Steam applied							
Steam released							
Vacuum commenced	9:30 A.M.	9:00 A.M.	1:00 A.M.	7:45 A.M.	1:50 P.M.	4:15 P.M.	7:05 P.M.
Creosote introduced	10:05 "	10:00 "	2:30 "	11:40 "	2:20 "	4:45 "	7:35 "
Pressure commenced	~~~	10:30 "	3:00 "	12:20 P.M.	2:50 "	5:10 "	7:50 "
Commenced forcing back	10:15 "	1:30 P.M.	3:50 "	2:35 "	3:40 "	5:15 "	9:35 "
Finished forcing back	10:45 "	2:00 "	4:15 "	3:00 "	4:10 "	5:40 "	10:00 "
Total time	1^{15} hrs.	5^{00} hrs.	3^{15} hrs.	7^{15} hrs.	2^{20} hrs.	1^{25} hrs.	2^{55} hrs.
Oil pressure at end (lbs.)	25	120	160	175	150	25	145
Vacuum indicated (in.)	20	24	25	25	24	21	23
Tank Gauge—	E 33,660	G 42650	G 38260	H 40920	D 39480	H 39120	H 37920
After filling	7,980	13840	9400	15960	14580	13520	13260
~~Saw~~ Low point	~~~	11660	7530	14760	13670	13000	11960
After forcing back	31,780	38950	34400	39120	37780	37580	36120
Temperature of tank	195°	200°	160°	150°	190°	150°	145°
Minimum in cylinder	175°	175°	160°	150°	160°	150°	145°
Maximum in cylinder	175°	180°	160°	150°	160°	150°	150°
Temperature of tank	180°	180°	130°	145°	190°	160°	145°
Treatment per cubic foot (lbs.)		16	16				
Treatment per tie (gals.)	2			2	2	2	2
Cu. ft. treated		1890	1890				
Ties treated	811			827	820	805	849
Absorption (lbs. or gals.)	1.98	15.92	16.46	2.04	1.99	2.10	2.07
Calculated absorption (gals.)	1622	3240	3136	1654	1640	1610	1698
Actual absorption (gals.)	1610	3225	3274	1692	1632	1695	1764
Specific gravity of oil	1.07	1.12	1.14	1.08	1.07	1.08	1.08
Per cent water in oil	0	0	0	0	0	0	0
	C. & A. R.R. Soft wood ties	Perry, Ia. Loblolly paving blocks	Perry, Ia. Loblolly paving blocks.	C. & A. R.R. Red oak ties	C. & A. R.R. Red oak ties	C. & A. R.R. Soft wood ties	C. & A. R.R. Red oak ties.

TREATING REPORT

THE KETTLE RIVER COMPANY ______________ 1910

PAVING BLOCKS

Charge No.	Treat. Lbs.	3 Inch Cages	3½ Inch Cages	4 Inch Cages	Cages	Cages	Cages	Cages	Cages	Cages	Cages	Cages	Cages	Cages	TOTAL Sq. Yds.	TOTAL Cu. Ft.
1202	16	14													826	1890
1275	16	14													826	1890

CROSS ARMS

Charge No.	Treat.	3¼x4¼ X Pcs.	2¾x3¾ X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	X X Pcs.	TOTAL F. B. M.	TOTAL Cu. Ft.

Charge No.	Treat.	Pcs.	Article	Size and Kind		F. B. M.	Cu. Ft.
964	2 gal.	811	Ties	6"×8"-8'	C.&A. soft.		
1436	2 gal.	827	Ties	6"×8"-8'	C.&A. red oak.		
1438	2 gal.	820	Ties	6"×8"-8'	C.&A. red oak.		
1439	2 gal.	805	Ties	6"×8"-8'	C.&A. soft		
1440	2 gal.	849	Ties	6"×8"-8'	C.&A. red oak.		

CREOSOTE, THE OIL USED IN WOOD PRESERVATION.

Creosote, as is generally meant by this name, is a by-product of coal tar, which is produced at many plants for the manufacture of illuminating gas and at by-product coke-oven plants. Coal is heated in a retort from which air is excluded and the gases produced are driven off and collected, the lighter ones first and then heavier ones as the distillation proceeds. The accompanying diagram shows that there are two other products of this distillation--coal tar and coke.

COAL

GAS | TAR | COKE

OILS LIGHTER THAN WATER | OILS HEAVIER THAN WATER (CREOSOTE) | PITCH

PHENOLS (TAR ACIDS) | NAPTHALENE | ANTHRACENE | RESIDUE

Diagram showing the derivation and composition of creosote.

A second distillation is made of the coal tar, and this also results in three products: (1) Oils with a specific gravity less than one, of which crude carbolic acid is a typical con-

stituent; (2) oils heavier than water, known as dead oils of coal tar, coal tar creosote, or most frequently, simply as creosote; and (3) a residue which remains in the retort, known as pitch. Creosote contains a large number of substances and is an extremely complex mixture of organic compounds, of which the so called tar acids or phenols, napthalene, and anthracene are the most important in wood preservation. The composition of these distillates is by no means constant, but varies not only with different coals but also with different treatments of the same coal. This variation has been one of the obstacles in getting good standard specifications for the oil. The same coal will yield at the same plant various qualities of coke, gas, and tar, depending on the amount of heat applied, the quality of air admitted, and the season of the year. When a low heat is applied a relatively small amount of gas and tar is evolved and the tar contains large quantities of compounds belonging to the paraffin series. On the other hand, with a high temperature much larger amounts of gas and tar are obtained and the predominant compounds of the tar, in nearly all cases, are those belonging to the aromatic series, such benzene, toluene, phenol, napthalene, anthracene, and so forth.

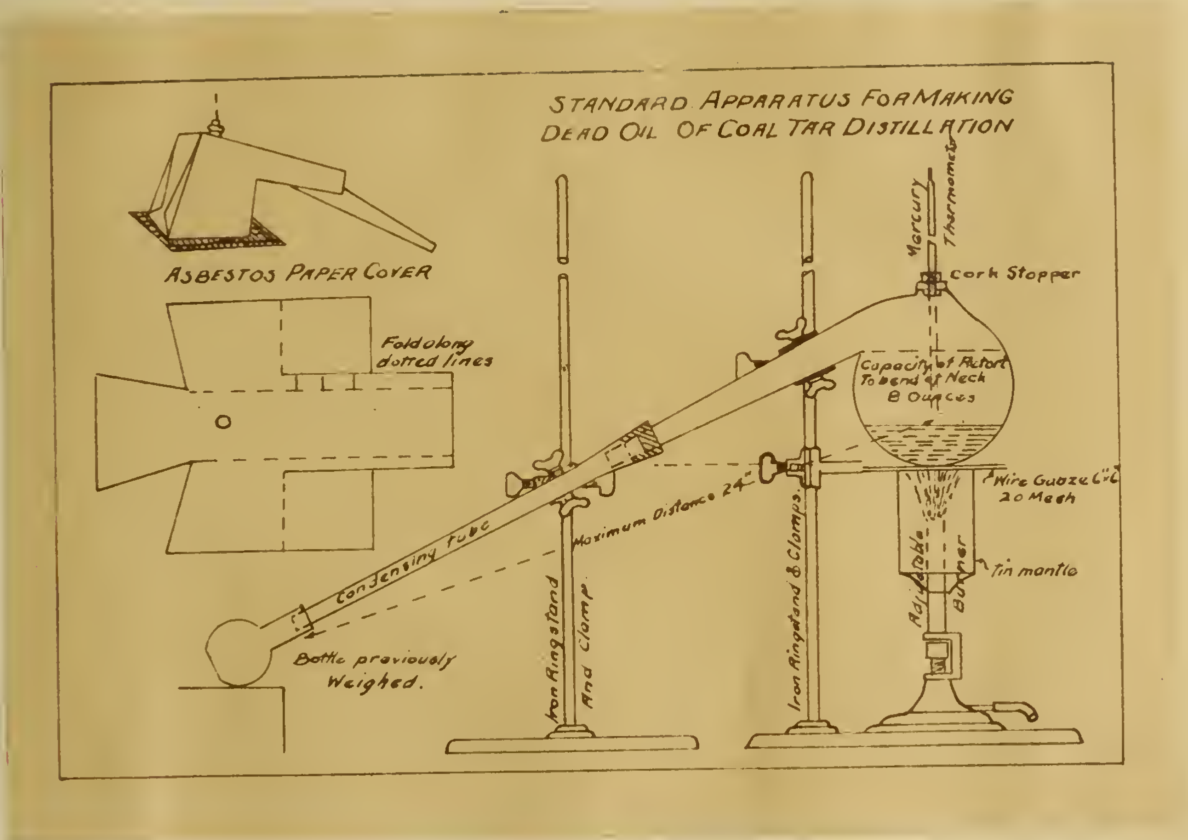
Never since timber treating began on a commercial scale in the United States has the domestic supply of creosote been equal to the needs of the industry. With the rapid development of wood preservation in recent years, the insufficiency of the home production of creosote has become more marked. In 1908 more than 56 million gallons of creosote were used in this country. Of this amount 69 per cent was imported (principally

from England and Germany, and a small amount from Canada) and only 31 per cent of the total supply was produced in this country. Were all the tar produced which the coal annually coked in the United States is capable of yielding, it would distill as much creosote as is now used by the wood preservers. Unfortunately, American operators do not even get the fullest use of the limited quantity of coal-tar for creosote alone; so, unless they can find a market for the associated products, it is not separated.

The chief requisite for a successful coal-tar creosote, i. e., one which shall preserve wood for an indefinite period of time, should be than the oil is composed of compounds which, because of their high-boiling points, will guarantee the greatest possible stability. Taking the oils as they are now manufactured, the endeavor should be to reduce the low-boiling fractions as much as possible, consistent with obtaining an oil which shall be fluid enough at all working temperatures to obtain a thorough and equal penetration throughout the mass of wood cells. A number of specifications for creosote have been worked up by different societies; perhaps the best of these and the one to commended is the standard specifications of the American Railway Engineering and Maintenance of Way Association as presented in their bulletin number 131 of January, 1911.

Some of the most important requirements of these specifications are as follows: The oil used shall be the best obtainable grade of coal-tar creosote; that is, it must be a pure product of coal-tar distillation and must be free from admixture

of oils, other tars or substances foreign to pure coal tar. It must be completely liquid at 38° C., and not more than two per cent of the water-free oil shall be insoluble in chloroform or benzol. The specific gravity of the oil at 38° C. must be at least 1.03, and should not exceed 1.10. When distilled according to the common method, that is, using 100 grammes of "dry oil" in an eight ounce retort (as shown in the following diagram), asbestos covered, with standard thermometers, bulb



one-half inch above the surface of the oil, and with a rate of distilling of one to two drops per second, the creosote, calculated on the basis of the dry oil, should show the following results. There should be no distillate below 200° C., less than five per cent below 210° C., less than 25 per cent below

235° C., and the residue above 355° C., if it exceeds five per cent in quantity, must be soft. The distillate between 210° and 235° C. shall deposit naphthalene salts on cooling to room temperature (20° C.) and the distillate between 315° and 355° C. shall yield solids on cooling to room temperature. During the distillation, the oil shall not show any evidence of decomposition, as indicated by the presence of dense white fumes in the condenser. The oil shall not contain more than three per cent of water.

In making distillations of oil, it is very important that all requirements be carried out fully, as slight variations from the specifications may make a big difference in the amounts of the distillates. Especially is this so in regard to the height of the thermometer bulb above the oil.

The following are some of the distillations that the writer made upon some of the creosote used by the Kettle River Company in different charges.

		Total Distillate to							
Use of Wood	Water	170° Cent.	210° Cent.	235° Cent.	270° Cent.	315° Cent.	355° Cent.	S. G. at 100° C.	Residue
Ties	1.5	0.3	4.3	27.9	44.9	52.1	59.2	1.090	Very soft
Ties	2.0	0.4	4.2	29.6	47.1	56.6	67.1	1.081	Soft
Paving Blocks	3.0	0.2	4.2	17.0	30.4	38.3	46.8	1.122	----
Paving Blocks	0.3	0.0	2.0	10.9	25.2	33.3	44.3	1.140	----

PHYSIOLOGICAL EFFECT OF CREOSOTE ON MEN HANDLING TREATED WOOD.

There has been a great deal of discussion as to whether creosote is injuricus or not to the men handling wood treated with it. This has been caused by the fact that there have been many lawsuits for damages by men who have claimed to have been disabled by the oil.

From data collected from various preserving plants, as given in the 1909 annual proceedings of the Wood Preservers' Association, it was shown that no employes were actually injured by the creosote though a few who had been troubled by it. If treated wood is handled while it is still hot with the oil, it may bother the men to a slight extent, or as they say, it "burns" them. Especially is this so in hot summer weather, and for this reason they prefer loading ties and other treated material in the evening or early in the morning while the air and wood are cool.

The oil, when hot, seems to work into the skin of the men and irritate it, sometimes festering the skin slightly. Occasionally the laborers are "burned" to such an extent that they have to "lay-off" for a half a day or so, but they are usually all right the following day. Some men can stand the effect of the oil much better than others, it depending upon the tenderness of their skin, but all seem to become accustomed to it af-

ter a short time. However, negroes are never bothered as much as white men. As an example of the effect of the oil upon men not accustomed to it, the writer noticed three young white fellows for their first time loading hot ties into a freight car. Not one of them was able to work the next day, and two of them were disabled for over a week with their arms bandaged in cotton. This was probably an unusual case.

After the surface creosote has soaked into the wood and the timber has cooled thoroughly, there are no injurious effects from handling the wood. Railroad laborers sometimes claim to be disabled from handling creosoted ties on the right of way but this is due to their dislike of treated wood since it is heavier and dirtier to handle.

ABSORPTION AND PENETRATION.

If a company intends to have wood treated at a preserving plant, it is always advisable that they have their own inspector at the plant. This is simply to assure the company as to the exact treatment that the wood receives and whether it is up to specifications or not. The inspector should examine the condition of the wood before treatment to see that it is thoroughly seasoned, he should read the gauges himself and compute the actual absorption, and he should watch his wood after treatment, noting the cars that it is shipped in.

The absorption is the amount of oil that is required to be injected per cubic foot or per tie. The amount varies with the purpose of the wood and is as given before, under the topic "Application of Pressure" on pages 42-46. A simple method of determining the absorption, one which is especially applicable to paving blocks is to take a fair sample of the wood from the charge, about a cubic foot in quantity, and weigh it before and after treatment. In case of blocks, they can be placed in a gunny-sack and thrown into the cylinder before the door is closed. The increase in weight of the wood gives the absorption. To be actually correct, an allowance should be made for the saps and moisture lost through the drawing of the vacuum, but this is small and may be disregarded.

The penetration of the oil varies with the kind of

wood, with its condition relative to seasoning, with the amount of oil to be injected, and with the method of treatment. Paving blocks subjected to a 16 to 20 pound treatment usually have a penetration running all through the block. Ties preserved with a light treatment of from two to two and a half gallons of oil per tie will have a penetration of from one quarter of an inch to an inch or more. Of course at the ends the depth of the penetration will be much greater, as the oil can readily follow the grain of the wood. Since it takes from a quart to two quarts of oil to paint a tie thoroughly, a two gallon treatment does not mean that a full two gallons are injected into the wood. However a good quarter of an inch to one-half of an inch penetration will protect any piece of wood provided that it is not cracked after treatment so that fungi and bacteria can get at the untreated part. On page 57 the borings taken from standard ties (6"x 8"x 8') treated with two gallons per tie show the penetration in various woods and also how the penetration will vary. It is very important that like woods be treated alone but this is sometimes impossible and consequently timber having great absorption power will take more oil than timber having small receptive qualities. On page 58 are shown some sections taken from loblolly paving blocks treated with 16 pounds per cubic foot.

Borings taken 1/4 inch deep from the sides of ties treated with two gallons of creosote.

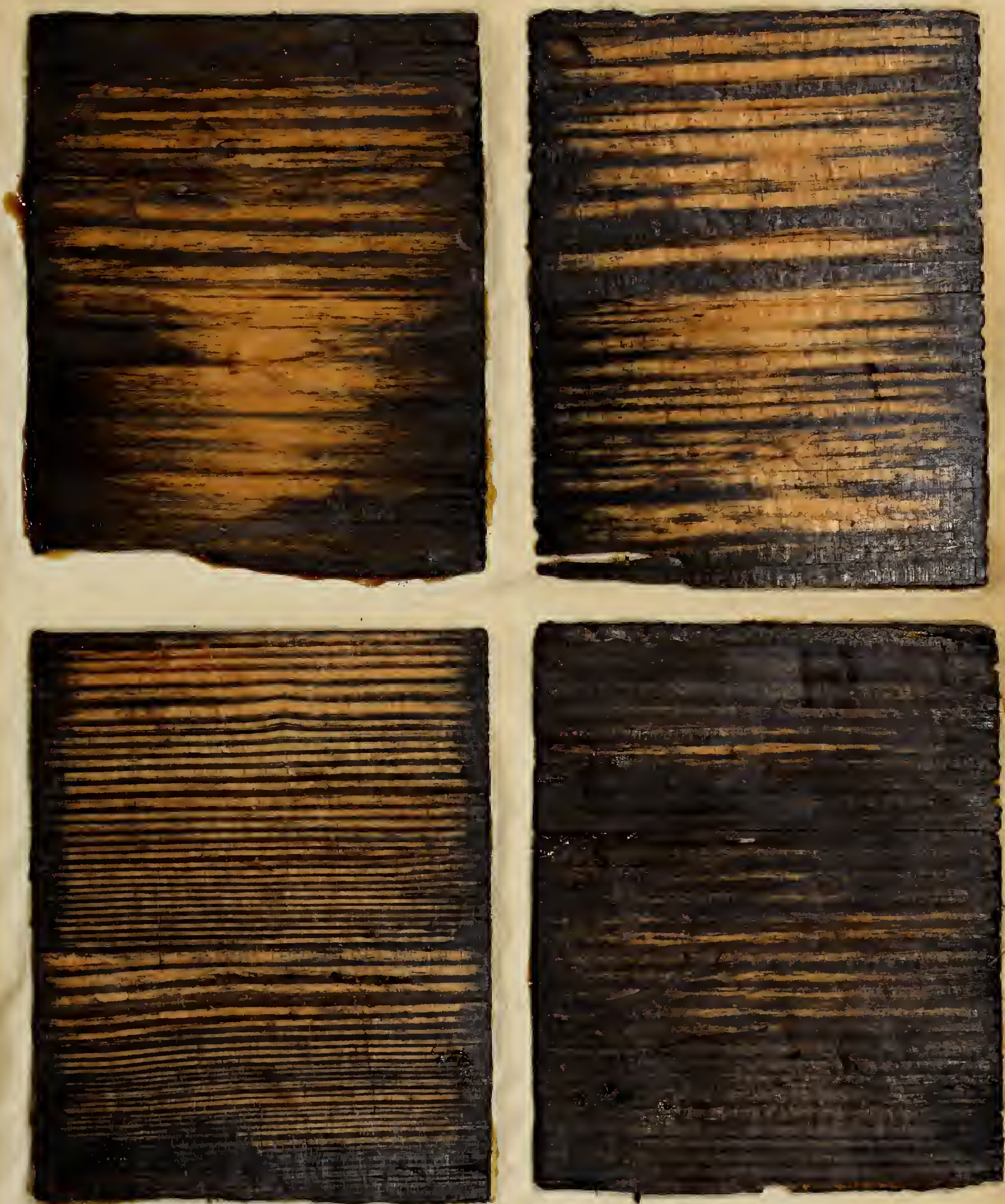
Gum--two different ties.

Red Oak.

Sycamore.

Ash.

Hickory.



Sections From Creosoted Loblolly Pine Paving Blocks

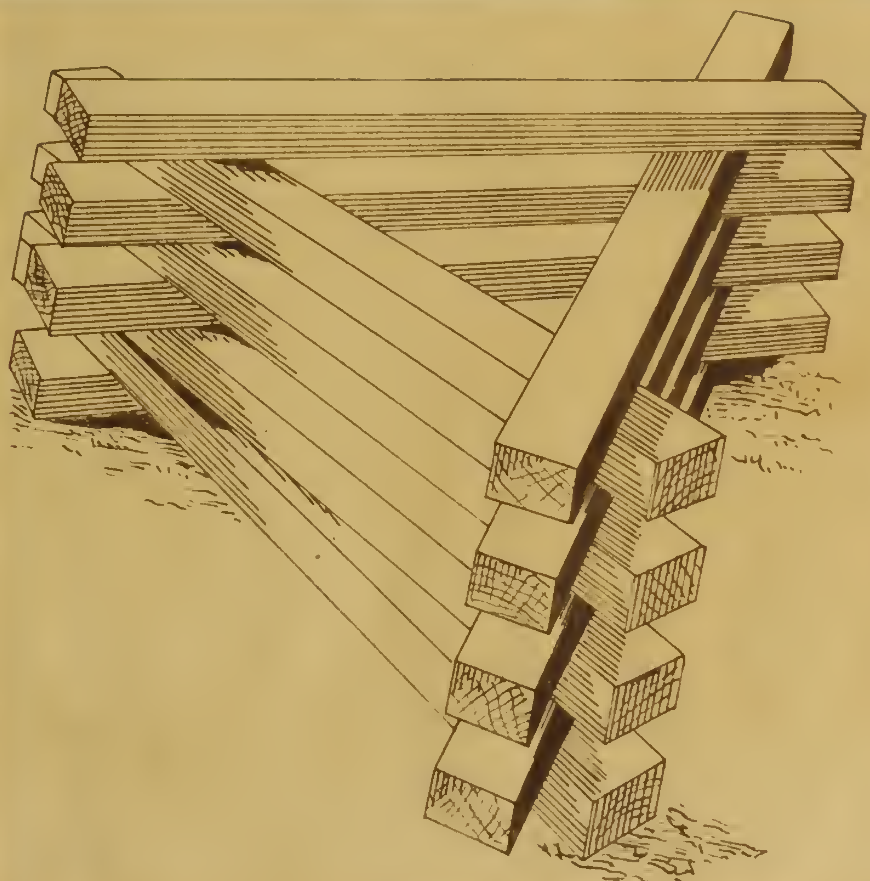
Treatment of 16 pounds per cubic foot.

STRENGTH OF TREATED WOOD.

There have been many experiments made upon treated wood to determine whether the strength of the wood is affected by the preservatives. While most of these experiments seem to show that the wood is usually weaker after treatment, this weakness is attributed to the steaming and excessive heat and also to the fact that the moisture which was absorbed during the steaming had not had time to dry out. Since creosoted wood is very slow to absorb moisture, it is equally slow in drying. Thus it is very important that the practice of steaming be discontinued and that all moisture be kept away from the wood if the treated timber is to show strength equal to that of the untreated. The general conclusions drawn by most experimentors is that the creosote does not penetrate the wood fibers but merely forms an external coating around them; hence in itself it can not appreciably affect the strength of the timber. In general the ultimate strength of treated wood depends, first upon the percentage of moisture remaining in the wood; and second, upon whether the wood has been subjected to injuriously high temperatures during the preliminary processes of steaming and vacuum, if these processes are employed.

It is to be recommended that whenever possible, treated wood be seasoned at least a month or so before it is brought in contact with the soil. When the wood is first treated, the

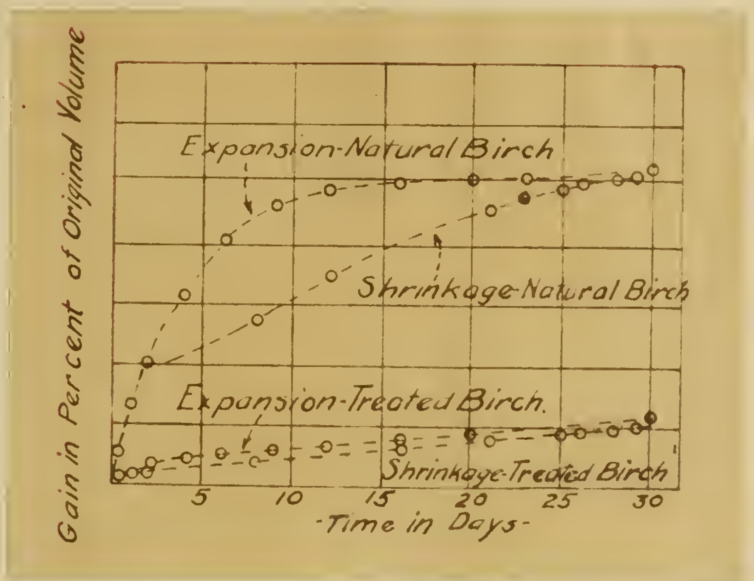
cell cavities are often filled with a watery solution and if zinc chloride is the antiseptic used, this water solution will aid the salt in leaching out when the wood is brought in contact with the soil. If, however, the treated timber is allowed to dry out, the salt is deposited on the cell walls and no leaching can take place as long as it remains in this condition. As it is often impracticable to season ties in the treating yard, they can be seasoned on the right-of-way. The form of pile best adapted for this is the triangular form as shown in the following diagram. The advantages gained from this form of



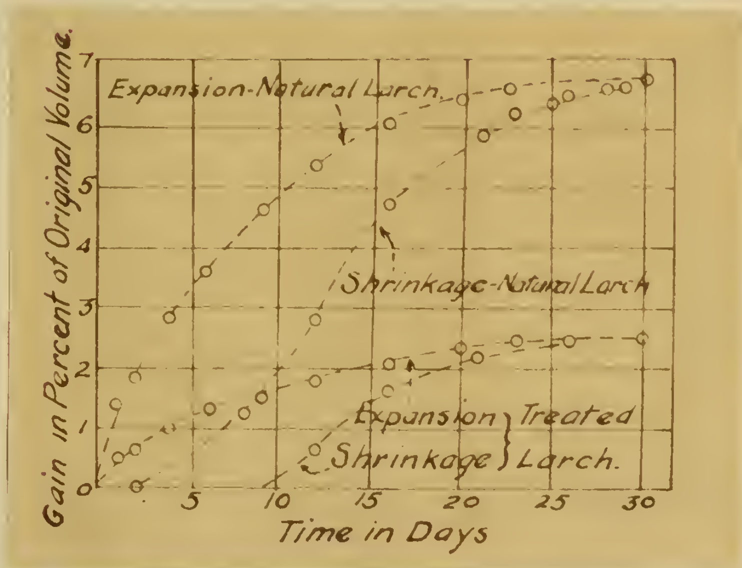
A triangular tie pile

pile is that the maximum rate of seasoning is secured, no tie is brought in contact with the ground in more than one point, and only a comparatively few ties are required, thus permitting numerous piles along the right-of-way, with a consequent saving in the labor of carrying the ties from pile to the track.

In the case of wooden paving blocks treated with creosote, the strength is of minor importance compared to its resistance to decay and absence of swelling. From some experiments performed at Purdue University, these latter qualities were found to have been attained with an unimportant loss of strength. The diagrams on the following page show how the expansion and shrinkage of natural larch and birch compare with the same qualities of the treated larch and birch.



Expansion and shrinkage of treated and untreated birch.



Exapnsion and shrinkage of treated and untreated larch.

LIFE OF TREATED WOOD.

The principal agents which destroy structural timbers are decay, fire, insects, marine borers, and mechanical abrasion. The following table from Bulletin 78 of the Forest Service shows the relative importance of these agents. It can

TABLE 1.—*Estimated annual destruction of cut timber in the United States.*[a]

[M feet B. M.]

Class.	Total destroyed annually requiring replacement.	Destroyed by— Decay.		Fire.		Insects.		Marine borers.		Mechanical abrasion.	
		Amount.	P.ct.	Amount.	P.ct.	Amount.	P.ct.	Amount.	P.ct.	Amount.	P.ct.
Ties	3,300,000	[b]2,871,000	87	....	....	16,500	½	....	....	412,500	12½
Poles	147,720	140,334	95	....	....	5,908	4	....	....	1,477	1
Posts	3,000,000	2,700,000	90	165,000	5½	120,000	4	....	....	15,000	½
Mine props	402,000	281,400	70	2,010	½	38,190	9½	....	....	80,400	20
Piles	191,520	9,576	5	....	....	....	....	181,944	95	....	....
Shingles	1,100	1,045	95	55	5	....	....	....	....	....	....
Lumber	2,625,000	1,863,750	71	131,250	5	315,000	12	52,500	2	262,500	10
Total	9,667,340	7,867,105	81	298,315	3	495,599	5	234,444	3	771,877	8

[a] The annual replacements of each class are found by dividing the total amount of timber in use by the estimated average life of the untreated timber. The quantities destroyed by decay, fire, etc., are of necessity only approximations.

[b] This figure includes destruction due to fire as well as to decay.

readily be seen with the exception of piles, that decay is far more destructive than all the others put together. As has been previously shown, strong antiseptics prevent the attack of fungi, bacteria, insects, and marine borers for a period equal to two or three times the life of the untreated wood provided tie-plates and screw-spikes are used to prevent abrasion.

In regard to fire, zinc chloride and creosote act somewhat differently. Zinc chloride is used largely in the

manufacture of fire-proffing compounds; it is very deliquescent in its nature, absorbing moisture from the air and therefore is not very combustible. Thus its presence in timber lessens its inflammability and to certain extent, fireproofs it. Creosote, on the other hand, is a very high boiling oil, that is, most of its ingredients boil and vaporize at very high temperatures, and consequently it has a very high flashing point. Timber freshly treated with creosote is more inflammable than untreated material, but its degree of inflammability gradually decreases as it grows in age, until after a certain length of time (about from three to six months), it is no more inflammable than untreated material. From that time on, the wood becomes less inflammable than untreated timber and finally reaches a point where very much heat is required to ignite it. This condition is due to the passing off of the lighter oils, those that vaporize readily, thereby leaving a deposit of heavier oils in the wood which have a strong tendency to fireproof the timber. There have been many striking instances to prove conclusively that creosoted timber that has seasoned is much less inflammable than untreated wood.

It is very important for future information that records of all treated wood be kept. Such devices as dating nails will answer this purpose well. If records are taken every two or three years, it will be possible to draw very definite conclusions in a decade or so. However, records or wood treated in the past have been taken with sufficient accuracy to draw some positive conclusions. The following extracts are taken

from the committee report of the American Railway Engineering and Maintenance of Way Association in 1909, and they give a good average of treated wood.

Creosoting may be relied upon to preserve piles from 20 to 25 or more years if they are injected with 16 to 24 pounds per cubic foot. The cuts on page 66 show well the effect of treating piles with creosote.

Creosoting at present cannot be relied upon to preserve ties more than 15½ to 19 years, an absolute maximum, unless the ties are protected against mechanical destruction. If badly injected, they perish from decay in 5 to 12 years.

Burnettizing, when well done, can be relied upon to preserve ties from 10 to 14 years. The amount to be injected varies with the proposed subsequent exposure. In arid climates one-fourth of a pound of dry zinc chloride per cubic foot may give good results. In moist and warm climates not less than one-half a pound per cubic foot should be injected.

The zinc-creosote process has been too recently introduced in this country to give very definite conclusions; however, it has given ties a life of 12 to 18 years in the track in Germany.

FIG. 1.—UNTREATED POLE OF SOUTHERN WHITE CEDAR (CHAMÆCYPARIS THYOIDES) AFTER FOUR YEARS' SERVICE

FIG. 2.—CREOSOTED LOBLOLLY PINE POLE AFTER EIGHTEEN YEARS' SERVICE. NO SIGN OF DECAY.

THE ECONOMY OF WOOD PRESERVATION.

Wood preservation, while important in its national aspect, is also of great personal importance to every user of timber exposed to decay or to the attack of insects. By lessening the cost of maintaining his wooden structures, fences, telephone lines, and railroad tracks, there is a direct saving in dollars and cents. Several specific examples will illustrate this well.

The average cost of an untreated fence post is 10 cents, and the cost of setting it is also about 10 cents, making the initial cost 20 cents. With an average life of eight years and compounding interest at 6 per cent, the annual charge for such a post is 3.2 cents. If given a preservative treatment at a cost of 12 cents, the life of the post is increased to 22 years. The initial cost is then 32 cents which compounded at the same rate, gives an annual charge of 2.6 cents. While a yearly saving of six-tenths of a cent per post may seem small, it is estimated that there are four billion posts in use and if all these were treated there would be a saving of about 24 million dollars per year. Moreover, the case cited is an average for the whole country, timber regions as well as prairie, and in many localities a much greater saving can be secured.

The following estimate is based upon the conditions

existing on the Atchison, Topeka, & Santa Fe Railroad line in New Mexico in 1885. The prolongation of life of the mountain pine there used is from a mean of 4½ years to about 12 years. For a period of twelve years:

Cost of ties in 12 years.

Untreated	Cost of tie, 2 2/3 x 35 cents......	$0.93	
	Cost of placing in track, 2 2/3 times	.40	
			$1.33
Treated	Cost of tie, one..................	$0.35	
	Cost of treating (zinc chloride)...	.15	
	Cost of placing....................	.15	
			$0.65

This makes a saving in twelve years of 68 cents per tie or 5 2/3 cents per tie per year. Figuring 2640 ties in each mile, there is a saving of $149.50 or approximately $150 per mile per annum. As the works built in 1885 consisted of two retorts, with an annual capacity of 400,000 ties, sufficient to renew 300 ties per mile on 1,333 miles, the annual saving on this basis would be something like $200,000. Their plant, the Las Vegas Works, cost about $30,000, a small part of the annual saving (about 15 per cent).

Considering the case of telephone poles: The average cost of a pole set in the line is about $7.00 and it lasts 13 years. Compounding at 6 per cent the annual charge amounts to 78 cents and this corresponds to a capital of $14.67 investted at 6 per cent, or for a mile of 40 poles, to about $587.00. Assuming that the average treatment costs $1.50, the initial cost would be $8.50, but the life of the pole would be increased to about 23 years. At the same rate of compound interest, the

annual charge would be 69 cents, which corresponds to an investment of $11.50, or $460.00 per mile as compared with $587.00 per mile in the other case. Thus, during the life of the treated pole a yearly saving of the interest on $127.00 will be effected for every mile of line. As there are about 32 million poles in use in the United States, an annual saving of $2,880,000 would follow from the proper treatment of them.

Similar specific examples could be taken up, but the following table summarizes very well the estimated financial saving per annum which would result from a creosote treatment of all kinds of structural timber which can be treated with profit.

TABLE 3.—*Estimated annual financial saving by proper preservative treatment.*

Class.	Initial cost.[a]			Cost of treatment.	Years life.		Annual charge.		Annual saving.	Quantity in use.	Total saving.
	Material.	Placement.	Total.		Untreated.	Treated.	Untreated.	Treated.			
Ties	$0.470	$0.20	$0.670	$0.35	7	17	$0.120	$0.097	$0.023	700,000,000	$16,100,000
Poles	4.000	3.00	7.000	1.50	13	23¼	.780	.690	.090	32,000,000	2,880,000
Posts	.100	.10	.200	.12	8	22	.032	.026	.006	4,000,000,000	24,000,000
Piling[b]	.100	.05	.150	.25	3½	21½	.050	.034	.016	4,000,000	1,800,000
Mine props[b]	.045	.23	.275	.11	3	13	.100	.040	.060	200,000,000	12,000,000
Lumber[c]	16.500	2.00	18.500	10.00	8	20	2.980	2.480	.500	[d]30,000,000	15,000,000
Total											71,780,000

[a] The initial cost is taken at the point of purchase, no allowance being made for freight charges.
[b] Charges per cubic foot.
[c] Charges per M feet B. M.
[d] Refers only to that adapted to treatment.

There has been much discussion as to whether light preservative treatments will prove practical. The following data on hemlock and tamarack ties, which being very close-grained woods absorb only a comparatively small amount of preservative, will show the real economy of such treatments.

Including freight and labor charges the cost of the

average untreated hemlock or tamarack tie when laid for use west of the Mississippi is estimated (by the Chicago and Northwestern Railway Company) to be about 75 cents. The cost of impregnation with zinc chloride is about 12 cents per tie, making the cost of the treated tie 87 cents. On the basis of an annual charge computed from the formula $r = R \frac{(1 + p)^n \times p}{(1 + p)^n - 1}$ in which r is the annual charge, R the initial expenditure, p the rate of interest, and n the years of the recurring period, the following statistics are derived, using the estimated life of an untreated tie as 5 years, and an interest rate of 4 per cent. The annual charge on an untreated tie costing 75 cents is 16.8 cents. For a treated tie costing 87 cents and lasting six years, the annual charge is 16.6 cents; lasting seven years, is 14.5 cents; lasting eight years, is 12.8 cents; and ten years, the estimated life of a treated tie, is 10.7 cents. These figures demonstrate that an added life of a single year makes the cost of treatment practicable, and an added life of five years (a conservative estimate) secures a saving of 36.3 per cent in the annual charge. Thus it can be seen that no matter how difficult the absorption of hemlock and tamarack may appear in comparison with that of the porous species, the treatment of these timbers is not unsatisfactory and results in a decided economy to both railroads and the forest resources of the country.

CONCLUSION.

As has been shown, the total yearly drain upon our forests, not counting loss by fire, storms, and insects, is about 20 billion cubic feet. Since the yearly growth is less than 7 billion cubic feet, or one-third of the amount of wood cut, great economy must be practiced in the use of wood, and that which is used must be preserved with an antiseptic treatment if a condition of equilibrium between timber production and consumption is reached. However, this condition can be attained and it is possible to produce on 450 million acres sufficient wood for a much greater population than we now have if conservation of the forests, economy of materials, and preservation of timber are practiced. The question of wood preservation is one of vital importance today since it is not only a large factor in preserving our forests but it also means a direct saving in dollars and cents to those who practice it. Antiseptic treatments either with zinc chloride or creosote, though preferably the latter, afford a great opportunity for the use of "dead" wood left from forest fires and for the so-called "inferior" timbers which in their natural state decay too rapidly to permit their use where a fairly long life is imperative.

Mr. W. F. Sherfesee, in charge of Wood Preservation of the Forest Service, in Bulletin No. 78, gives a very good

summary of the situation when he says:

"There is abundant evidence to show the life of properly treated wood. Even in this country there are many examples of poles and other timbers creosoted 20 and even 30 years ago, which today are apparently as sound as when first set in the ground. In Europe, where wood preservation is an older industry, the results are still more marked. There have been failures, but in every instance they can be traced to fraudulent or incompetent work, insufficient impregnation, or improper preparation of the timber, or some similar cause. The economy of preserving structural timber from decay is no longer a matter of argument. It has been decided definitely in the affirmative. The question now is not, 'Does wood preservation pay?' but 'What process and preservatives are best suited for a particular condition?'"